

DRAWINGS ATTACHED

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(54) BURNER OF GASEOUS FUEL AND APPARATUS
 EMBODYING SAME

(71) We, AMERICAN GAS ASSOCIATION, INC., a corporation of the State of New York, United States of America, of 605 Third Avenue, New York, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Various devices are known in the prior art for producing swirling flames by injecting a gaseous fuel into a swirling air flow within a cylindrical conduit. One such device is shown, for example, at pages 47 and 48 of Research Bulletin 96 of American Gas Association Laboratories entitled "New or Unusual Burners and Combustion Processes". The latter type of device utilises a plurality of slots in the walls of a cylindrical conduit to introduce a swirling pattern of air into the conduit, and the gaseous fuel is injected into the conduit in the slot region, where it mixes with the swirling air and combustion takes place.

The present invention relates to a new and useful gas burner and air heating apparatus employing a different structural arrangement than that described above with a corresponding different flow pattern of air and gas. The resultant burner is versatile, particularly with respect to the type and location of flame which it is capable of producing and, in one preferred embodiment, provides a particularly simple and efficient manner of heating air or similar gases.

In accordance with the invention there is provided a burner for gaseous fuel comprising a conduit having one substantially-closed end and an opposite open end, means for discharging gaseous fuel into the conduit near the closed end, and forced-draught means for providing a forced draught of an oxidising gas such as air through aperture

means in the sidewall of the conduit, and the aperture means being so configured that the injected oxidising gas flows in a swirling pattern around the interior walls of the conduit with a motion including a substantial "upstream" component toward the closed end of the conduit, so that enough of the combustion air reaches the gaseous fuel upstream of the aperture means to produce a combustible mixture upstream of the aperture means.

In the preferred form of the invention, the resultant flow upstream of the aperture means is in the nature of a vortex, involving a rotational component of flow in a thin layer about the interior walls of the conduit plus the abovementioned upstream component, so that the swirling stream travels upstream to the vicinity of the closed end of the conduit where it reverses direction and returns substantially along the centre of the conduit, past the aperture means, and thence to the open end of the conduit. To produce a short flame, the gaseous fuel is preferably discharged into the conduit substantially along the same direction of the swirling motion of air. By adjusting the relative amounts of gaseous fuel and of air brought in through the aperture means in the conduit walls, it is possible to produce a substantially completely-combusting flame entirely upstream of the aperture means, or a similar flame extending further downstream in the conduit, or a highly-radiant flame extending from upstream of the aperture means outward from the open end of the conduit.

In a preferred embodiment of the invention utilised for air heating, the conduit is provided with second aperture means downstream of the above-mentioned first aperture means, through which additional air or other gas is passed to mix with the hot combustion gases produced by the flame in the conduit. Preferably this second aper-

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ture means produces a flow of air or other gas into the conduit in a swirling motion opposed to the direction of swirl of the air introduced by the first aperture means, so as to produce good mixing of the hot combustion gases and the air entering through the second aperture means. The latter arrangement is particularly useful, for example, in heating the air for a clothes dryer with the burner operated under conditions in which the flame is restricted to the region upstream of the first aperture means. It may also be utilised for such purposes as an afterburner for an incinerator, in which residual gas-borne materials are introduced through the second aperture means and burn within the conduit, in which case enough fuel and combustion air are injected to produce a flame extending downstream to the second aperture means.

Particularly for applications in which the flame is to be confined to the upstream side of the first aperture means, the first aperture means may comprise an arrangement of slots directed at an acute angle to the axis of the conduit in such direction as to enhance the upstream flow of the swirling combustion air. In such applications, primary air may also be admitted near the closed end of the conduit, either premixed with the gaseous fuel or by leakage through other openings near or in the closed end of the conduit. Where a radiant, highly-luminous flame extending outwardly from the conduit is desired, the gaseous fuel preferably contains substantially no primary air and the upstream end of the conduit is preferably hermetically sealed to prevent substantial leakage of air into that portion of the conduit.

The invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective schematic representation of a clothes dryer utilising a burner constructed in accordance with the invention,

Figure 2 is an elevational section of the burner shown in Figure 1,

Figures 3, 4 and 5 are horizontal sections of the burner of Figure 2, taken along the lines 3-3, 4-4 and 5-5, respectively,

Figure 6 is a schematic perspective view illustrating the air flow path and flame shape produced in the burner of Figure 2 in a preferred form thereof,

Figure 7 is an elevational sectional view of an incinerator system utilising as an after-burner a burner constructed in accordance with the invention,

Figure 8 is a sectional view taken along the line 8-8 of Figure 7,

Figure 9 is an end elevation view, and Figure 10 is a bottom plan, of another form

of burner in accordance with the invention for producing a radiant flame,

Figure 11 is a plan of the burner of Figure 9 to a reduced scale, showing the configuration of the flame produced, and

Figure 12 is a side elevation view of another form of the burner of the invention.

Referring now to the embodiment of the invention illustrated in Figures 1 and 2, in which it is shown in its application to a clothes dryer, the gas burner comprises a cylindrical conduit 10 of heat-resistant material such as steel, having a closed lower end 12 and an open upper end 14. Gaseous fuel, such as natural gas, is introduced into the conduit 10 from a gas nozzle 16 mounted by a bracket 17 and supplied from a gas line 18 by way of a gas control 19 for adjusting the rate of gas supply to the burner. As shown in Figure 5, the gaseous fuel is released near and along the interior wall of the conduit 10, at right angles to the axis of the conduit 10, so as to flow primarily about the inner wall of the conduit in a counter-clockwise sense as viewed from above. No flame retaining means is used at the outlet orifice of the burner nozzle. A pilot burner 20 provides a pilot flame 21 at the lower end of the conduit 10 adjacent to a pilot hole 22 in the side-wall thereof. Fuel for the pilot is supplied from a gas line 23.

A first set of three rectangular slots 24, 25 and 26 is provided in the conduit 10 in a region displaced substantially above the lower end 12 of the conduit 10, the slots in this example being identical with each other and coextensive along the conduit. The slots 24, 25 and 26 are equiangularly spaced about the conduit 10 and have associated with them directing vanes 28, 30 and 32, respectively, which may be simple punched or bent-in tabs which, when so formed, also produce the corresponding slots. The vanes are all directed in the same rotational sense within the conduit 10, namely counterclockwise as viewed from above.

Spaced along the conduit 10 toward its open end from the set of slots 24, 25 and 26 is a second set of apertures in the form of rectangular slots 40, 42 and 44 disposed equiangularly about the conduit 10 and having respective vanes 46, 48 and 50 associated therewith (see Figure 3). The set of slots 40, 42, 44 and the vanes 46, 48, 50 may be formed in the same manner as the slots 24, 25, 26 and the vanes 28, 30, 32, except that the vanes are oppositely directed about the axis of the conduit 10. Accordingly, air pulled into the conduit 10 through the slots 40, 42, 44 tends to whirl about the conduit 10 in an opposite direction to that pulled into the slots 24, 25, 26.

The burner conduit 10 may be mounted

in any convenient manner on a cabinet structure 51 of the clothes dryer of Figure 1, as in a portion of the cabinet located behind an enclosed drying chamber 52, in which location room air is freely available to the slots in the conduit 10. An exhaust blower 54 is mounted on the rear of a bulkhead 56 with its outlet 58 free to discharge air into the room.

The upper end of the conduit 10 contains a right-angle bend 55, and its open outlet end 14 communicates with the interior of the drying chamber 52 by way of a corresponding opening in the bulkhead 56.

The drying chamber 52 contains the usual rotating drum (not shown) in which the clothes to be dried are placed, as by way of a door in the front of the cabinet.

Accordingly, the exhaust blower 54 induces a flow along a path extending from the room into the slots 24, 25, 26 and the slots 40, 42, 44 through the open end 14 of the conduit 10, into the drying chamber 52, thence into an inlet opening 60 for the blower 54, and finally outward to the room, as indicated by the curved arrows in Figure 1.

Without thereby in any way limiting the scope of the invention, one typical set of dimensions and operating conditions for the gas burner of Figures 1 and 2 may be as follows.

Inner diameter of the conduit 10	4 inches
Spacing of the centre of the fuel nozzle 16 from the lower end 12 of the conduit 10	1/4 inch
Distance from the lower end 12 to the lower edges of the slots 24, 25, 26	3 1/2 inches
Length of the slots 24, 25, 26 and 40, 42, 44	4 inches
Width of the slots 24, 25, 26 and 40, 42, 44	1 inch
Inward projection of the vanes 28, 30, 32 and 46, 48, 50	3/8 inch
Distance from the upper edge of the slots 24, 25, 26 to the lower edge of the slots 40, 42, 44	7 inches
Distance along the centre of the conduit 10 from the top of the slots 40, 42, 44 to the open end 14	10 inches
Diameter of the pilot hole 22	1/4 inch

With these dimensions, a blower outlet rate of about 170 cubic feet per minute (c.f.m.), and a natural-gas input flow rate from the nozzle 16 of about 0.5 c.f.m., the total flow rate into the slots 24, 25, 26 was approximately 14 c.f.m. and that into the slots 40, 42, 44 approximately 70 c.f.m.

With these operating conditions and dimensions, substantially complete com-

bustion was obtained in a flame zone limited to the portion of the conduit 10 entirely below the lower end of the slots 24, 25, 26 and the rate of delivery of hot air to the drying chamber was comparable to that in conventional clothes dryers. No problems of accumulating soot on the burner nozzle were encountered.

The general form of the flame produced in this example is shown in Figures 2, 5 and 6, the direction of air flow being indicated by the arrows therein. The air flow through the combustion-air slots 24, 25, 26 whirls in a counter-clockwise sense about the interior of the conduit 10, and, due to the forced-draught suction exerted by the eductor blower 54, eventually passes in the downstream direction through the open end 14 of the conduit 10. However, apparently due to turbulence at the upstream edges of the combustion-air slots and to the effect of centrifugal force in flattening the whirling air stream against the conduit walls, a portion of the whirling air has a substantial upstream component so that it moves in a generally helical path toward the upstream closed end of the conduit 10; upon reaching the vicinity of the closed end, the only free path for escape is downstream through the centre of the whirling air pattern, past the combustion slots to the region of the second set of air-mixing slots 40, 42, 44 and finally out of the open end 14 of the conduit 10.

The nozzle 16 releases gaseous fuel into, and preferably generally along the direction of motion of, the air stream near the closed end of the conduit 10. The resultant flame is in the form of a hollow cylinder, with its outer wall spaced slightly inwardly from the wall of the conduit 10, the conduit walls being cooler than would be expected in view of the hot flame contained therein. The flame is not attached to the burner nozzle, but instead has a form determined primarily by the air flow rather than by the form of the stream in which the gaseous fuel is discharged. In this example the pilot hole 22 permits some leakage of air into the otherwise closed end of the conduit 10, but for the present purposes this is not harmful and in fact tends to enhance the combustion.

The distance between the closed end 12 and the adjacent ends of the combustion slots can be varied substantially, as can the number of combustion slots. External, rather than internal, vanes can be used, although internal vanes are preferred. The length of the combustion slots can also be varied substantially, although slots which are too long or too short tend to produce longer, softer flames. To produce a hard, short flame the gas-nozzle orifice is preferably located close to the closed end of the

conduit 10 and tangential to a circle concentric with the conduit axis. This prevents disruption of the air-flow pattern, and also apparently assists in allowing the air stream to lift the flame off the nozzle orifice thereby to permit a certain amount of beneficial primary aeration of the gaseous fuel as it emanates from the orifice before it is burned. A similar beneficial effect can be obtained by locating the gas supply orifice outside the conduit 10 and injecting the gaseous fuel through a hole in the side-wall of the conduit, so that outside primary air is entrained by the fuel-gas stream.

The conduit 10 need not be cylindrical but can have other shapes, including conical tapers, although shapes having circular cross-sections are preferred. Increasing the fuel input rate and the combustion-air input rate proportionately increases the length of the flame zone without, however, adversely affecting completeness of combustion; decreasing the ratio of combustion air to fuel tends to produce longer flames, yellow-tipping and luminous flames.

In the embodiment of Figure 1, the hot combustion gases flow in the conduit 10 to the second set of slots 40, 42, 44, which serve to introduce counter-rotating dilution air and thoroughly mix it with the hot combustion gases. This ensures that the clothes to be dried will not be subjected to unduly hot or scorching temperatures.

The short flame produced by the embodiment of Figure 1 enables a short overall length for the conduit 10 convenient for insertion in the back of otherwise-conventional dryers, and avoids the direct exposure of the flame to the exterior by way of the slots which would occur if the flame occurred in the slot region. The use of the two spaced sets of slots, in a simple cylindrical conduit, provides efficient uniform air heating in a compact, inexpensive burner.

It will be understood that conventional control and safety arrangements will ordinarily be used in a commercial form of the dryer of Figure 1. For example, a pressure switch 72 is preferably mounted on the blower outlet to sense outlet pressure and prevent supply of gaseous fuel to the burner unless the blower is fully operative.

Turning now to the embodiment of the invention shown in Figures 7 and 8, the burner is shown in its use as an after-burner to oxidise smoke and odoriferous vapours in the effluent gases from an incinerator. The incinerator itself, shown schematically, may be conventional and comprises an incinerator chamber 100 having refractory walls such as 102, 104, 106, 108, a burner 110, and a grate 112 for supporting refuse to be burned. The rear

wall 104 stops short of the top 113 of the incinerator so that hot combustion gases can flow over the rear wall on each side and downward through side channels 116 and 118. The channels 116 and 118 are separated by a central vertically-extending chamber 120 except at their lower ends, where they merge and supply hot combustion gases to the exterior upper end of a burner conduit 122. A partition 124 fits about the middle of the burner conduit 122 and prevents further downward passage of the hot combustion gases. Four equiangularly-spaced slots such as 126 in the wall of the upper end of the burner conduit 122 permit the hot combustion gases to flow into the conduit 122 and upward through the chamber 120 to an eductor blower 132 and an outlet stack 133. A motor 134 drives the blower 132. The incinerator burner 110 is provided with conventional fresh-air inlet means, and the eductor blower 132 therefore produces a flow of hot combustion gases along the path described above and indicated by the broad arrows in the Figures.

The conduit 122 is provided with another set of four equiangularly-spaced slots such as 140 in its sidewall for introducing combustion air. The slots 126 and 140 may all be of the same size and shape. As in the burner of Figure 1, each slot is provided with a directional vane, and the vanes of the slots 126 are directed to swirl hot combustion gases in a sense opposite to that of air entering the slots 140. Fresh air is provided to the slots 140 by way of a rear opening 144. A gaseous fuel supply line 146, provided with a flow control 148, supplies gaseous fuel to the conduit 122 near to its closed bottom end 150 and along the direction of swirl of combustion air entering the slots 140. A pilot line 52 and pilot hole 154 are again provided for ignition purposes. The suction due to the eductor blower 132 draws air into the combustion slots 140 in a swirling flow, as in the embodiment of Figure 1.

The gaseous input supply rate is adjusted, in conjunction with the amount of combustion air drawn into the slots 140, to provide a blue flame 160 extending upward from the closed bottom 150 of the conduit 122 to just above the upper slots 126. Accordingly the smoke and odoriferous components of the hot combustion gases from the incinerator combustion chamber pass through the hot flame zone of the after-burner, and are oxidised and eliminated or rendered inoffensive.

In one typical embodiment of the system shown in Figures 7 and 8, the input to the incinerator burner 110 was 15,000 BTU per hour, and that to the after-burner fuel supply line was 25,000 BTU

per hour. The outlet flow rate from the stack 133 was 25 c.f.m., and had a CO₂ content of about 3%. The conduit 122 had a diameter of 3 inches, and two sets of four slots were used in the conduit 122, each slot being 3/4 inch wide and 1 1/2 inches long. The two sets of slots were spaced vertically from each other by one inch, the partition 124 being positioned half-way between the sets of slots. The lower edge of the lower set of slots was 1 1/2 inches above the bottom 150 of the conduit 122.

The embodiment of the invention shown in Figures 9, 10 and 11 produces a highly-radiant extensive flame suitable for industrial use in heating furnace charges such as glass. In this case the burner has only one set of slots, used to introduce the combustion air.

More particularly, a motor 200 operates a blower 202 to force air into a cylindrical conduit 206 by way of a manifold 207 and six vaned slots 208 equiangularly-spaced about one conduit. Again, the vaned slots direct the combustion air in a swirling flow having a substantial peripheral component toward the closed end 210 of conduit 206, although all the air eventually exists from the conduit 206 through its open end 212. Again, the gaseous fuel is introduced upstream (i.e. toward the closed end of the conduit) from the slots. However, in this case two diametrically-opposed gaseous fuel supply lines 220 and 222 are used, near the closed end 210 of the conduit 206. Since in this case a short blue flame is not desired, the fuel supply orifices 230 and 232 are directed radially inward, and the closed end of the conduit 206 is hermetically sealed to prevent inward leakage of fresh air. Ignition can be provided by means of a manually-applied torch. A highly-radiant flame is thereby produced which extends from the region below the slots outward for a long distance, typically four or five feet. The outlet end 212 of the conduit 206 may be sealed in an opening in the wall 240 of a glass-heating furnace, for example. The general nature of the resultant long, highly-radiant flame 300 is represented in Figure 11.

In the present embodiment, the rate of fuel input is made relatively high compared with the combustion-air supply rate, so that there is a strong concentration of gaseous fuel near the axis of the conduit 206 and a strong fuel-concentration gradient radially of the conduit. This apparently produces a high degree of gas cracking and carbon-particle formation resulting in the highly-radiant flame. The degree of radiance obtained is superior to that of many conventional radiant-flame burners. In addition, the flame typically reaches a

maximum radiance at a shorter distance from the burner, a characteristic which can be exploited in obtaining more uniform furnace heating.

As an example only, to produce a radiant flame having a length of 5 feet the burner may be constructed and operated as follows. The conduit 206 may be 6 inches in diameter and 11 3/8 inches long, and each of the six slots may be one inch wide and 4 3/8 inches long and centrally positioned longitudinally of the conduit. The combustion air input rate may be 2,250 cubic feet per hour, and the fuel input rate 750,000 BTU per hour total for both supply lines, or 750 cubic feet per hour.

Figure 12 illustrates a construction for enhancing the upstream flow, particularly when a short blue flame is desired, as in the embodiment of Figure 1. In this case all parts may be like those of the burner of Figure 1, except that the combustion air slots 400 are tilted upstream at an angle A with respect to the axis of the conduit. Parts corresponding to those of the burner of Figure 1 are indicated by the same numerals with the suffix B. It will be understood that in this and other embodiments of the invention the directing apertures may take a form other than vaned rectangular slots.

Besides the advantages mentioned above, the positioning of the gaseous fuel inlet upstream of the slots offers an additional freedom of mechanical design, and clears the slot region of fuel-supply apparatus which would otherwise interfere with the establishment of a predictable smooth swirling flow of combustion air at and adjacent the slots.

While the invention has been described with particular reference to specific embodiments thereof in the interest of complete definiteness, it will be recognised that it may be embodied in a large variety of forms diverse from those specifically described without departing from the scope of the invention as defined by the ensuing claims.

WHAT WE CLAIM IS:—

1. A burner of gaseous fuel, comprising a conduit having a substantially closed end and an open end, aperture means in the sidewall of said conduit spaced from said closed end, means for establishing a positive pressure of an oxidising gas at the exterior of said aperture means, relative to the gas pressure at said open end, thereby to establish a flow of said oxidising gas from the exterior through said aperture means to said open end of said conduit, and inlet means for discharging a gaseous fuel into said conduit upstream of said aperture means, said aperture means comprising flow-directing means for directing said flow of

oxidising gas from said aperture means initially in a swirling path around the interior walls of said conduit with a component of flow upstream toward said inlet means, thereby to produce a swirling combustible mixture of said gaseous fuel and said oxidising gas upstream of said aperture means.

2. A burner according to claim 1, in which said aperture means comprises at least one slot through said sidewall.

3. A burner according to claim 2, in which said at least one slot extends parallel to the ends of said conduit.

4. A burner according to claim 2, in which said at least one slot extends at an acute angle to the axis of said conduit to enhance the upstream flow of said oxidising gas.

5. A burner according to any of claims 2 to 4, comprising a vane within said conduit along the edge of said slot.

6. A burner according to claim 5, in which said vane is a punched-in tab integral with said conduit wall.

7. A burner according to claim 1, in which said aperture means comprises a set of slots along the sidewall of said conduit.

8. A burner according to any of claims 1 to 7, in which said inlet means is oriented to discharge said gaseous fuel transversely to the axis of said conduit substantially along the direction of said swirling path of the oxidising gas.

9. A burner according to any of claims 1 to 8, in which said means for establishing a positive pressure and said inlet means are adjusted to produce an upstream flow of the oxidising gas sufficiently large, compared to the flow of said gaseous fuel, to produce substantially complete combustion of said gaseous fuel when ignited and to limit the resultant flame due to said combustion to a flame zone entirely upstream of said aperture means.

10. A burner according to any of claims 1 to 9, comprising second aperture means in the sidewall of said conduit, spaced downstream from said first-mentioned aperture means, for introducing a second swirling gas flow into said conduit by way of said second aperture means, said second aperture means being configured to cause said second gas flow to swirl oppositely to said swirling flow of oxidising gas.

11. A burner according to any of claims 1 to 10, in which the interior of said conduit is cylindrical.

12. A burner according to claim 10, in which said combustible mixture, when ignited, produces a flame extending to said second aperture means.

13. A burner according to any of claims 1 to 8, in which said conduit terminates adjacent to the downstream side of said

aperture means and in which the rate of supply of said gaseous fuel is sufficiently low that said combustible mixture, when ignited, produces a highly radiant flame extending beyond the open end of said conduit.

14. A clothes dryer system, comprising a drying compartment for receiving clothes to be dried, and having an air inlet and an air outlet, a conduit having a closed end and having an open end and communicating with said air inlet, said conduit having first aperture means in the sidewall thereof spaced from said closed end and having second aperture means in said sidewall spaced from said first aperture means in the direction of said open end, and means in the direction of said open end, and means for providing a forced draught of air through said first and second aperture means into said conduit, and then in sequence through said air inlet, said drying compartment and said outlet, said first aperture means comprising means for directing said forced-draught air passing there- through in a flow which swirls around the interior walls of said conduit with a substantial component in the direction of said closed end, means for releasing gaseous fuel into said conduit between said closed end and said first aperture means thereby to produce an inflammable mixture of said fuel and said forced-draught air in said conduit between said closed end and said said first aperture means, said second aperture means comprising means for directing said forced-draught air passing therethrough in a flow which swirls about the interior of said conduit in a sense opposite to that of said swirling flow produced by said first aperture means, and said forced-draught of air and said gaseous fuel being supplied at a rate to produce a flame in said conduit, when said combustible mixture is ignited, which is limited to the portion of said conduit between said closed end and said first aperture means.

15. A dryer according to claim 14, in which said means for providing a forced-air draught comprises an eductor blower having its inlet connected to said outlet of said drying compartment.

16. A dryer according to claim 14, in which said conduit has a substantially cylindrical interior surface, said first aperture means comprise a plurality of slots and said second aperture means comprise a second plurality of slots.

17. An incinerator system, comprising means for incinerating substances to produce combustion gases containing objectionable oxidisable materials in vaporous or fine-particulate form, a gas burner comprising a conduit having a closed end and an open end, inlet means for releasing

gaseous fuel into said conduit adjacent said closed end, a first set of aperture means in a side wall of said conduit spaced from said closed end, means for passing a forced draft of combustion air through said first aperture means to said open end, said first aperture means comprising flow-directing means for directing said combustion air from the aperture means initially in a swirling path around the interior walls of said conduit with a component of flow upstream toward said inlet means, thereby to produce a swirling combustible mixture of said gaseous fuel and said combustion air upstream of said first aperture means, a second set of aperture means spaced toward said open end from said first aperture means, and means for passing said combustion gases through said second aperture means to said open end.

18. A system according to claim 17, in which said first aperture means are exposed to atmosphere and in which said means for passing said combustion gases through said second aperture means and said means for passing a forced draught comprise an eductor blower connected to said open end.

19. A system according to claim 17 or 18, in which said first aperture means comprise slots in the sidewall of said conduit for swirling said forced-draught air about the interior walls of said conduit in one rotational sense, and said second aperture means comprise slots in the sidewall of said conduit for swirling said combustion gases about the interior of said conduit in the opposite rotational sense.

20. A system according to claim 19, in which the rate of supply of said fuel and of said forced-draught air is such as to produce a flame extending from adjacent said closed end to said slots of said second aperture means when the combustible mixture in said conduit is ignited.

21. A radiant-flame burner comprising a conduit having a closed end and an open end, aperture means in the side wall of said conduit spaced from said closed end, blower means, manifold means for receiving air from said blower means and delivering it to the exterior of said aperture means to establish a flow of combustion air through said aperture means to said open end of said conduit, and means for discharging gaseous fuel into said conduit between said closed end and said aperture means, said aperture means comprising flow-directing means for directing said combustion air from said aperture means initially in a swirling path around the interior walls of said conduit with a component of flow upstream toward said fuel-discharging means, thereby to produce a swirling combustible mixture of said gaseous fuel and said combustion air upstream of said aperture means, and the rate of supply of fuel to said fuel-discharging means and the rate of supply of air by said blower means being such as to produce incomplete combustion in said conduit when the fuel-air mixture therein is ignited and a radiant flame extends outward from said open end of said conduit.

22. A burner according to claim 21, in which said fuel-discharging means comprise a plurality of gaseous-fuel nozzles for discharging gaseous fuel substantially perpendicularly to the axis of said conduit.

23. A gaseous fuel burning apparatus constructed and arranged substantially as herein described with reference to Figures 1 to 6, Figures 7 and 8, Figures 9 to 11, or Figure 12 of the accompanying drawings.

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FIG. 1.

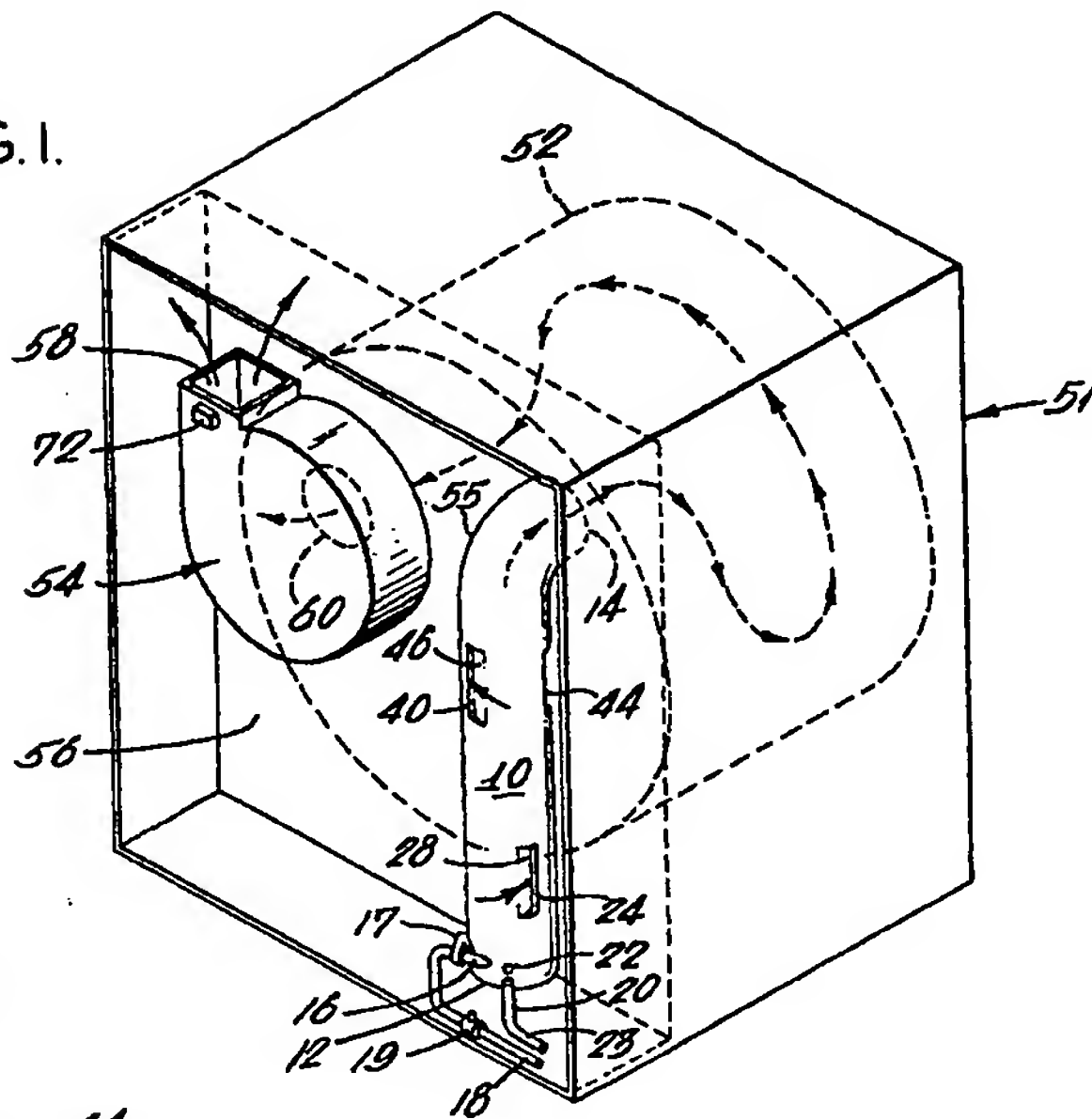


FIG. 2.

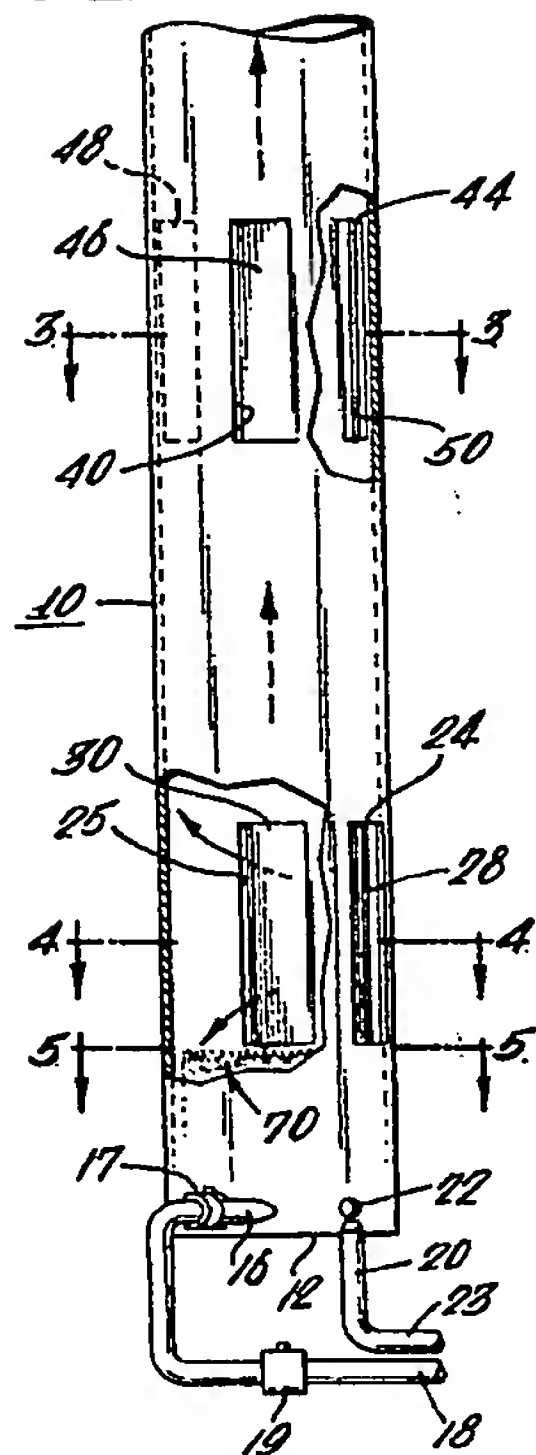


FIG.3.

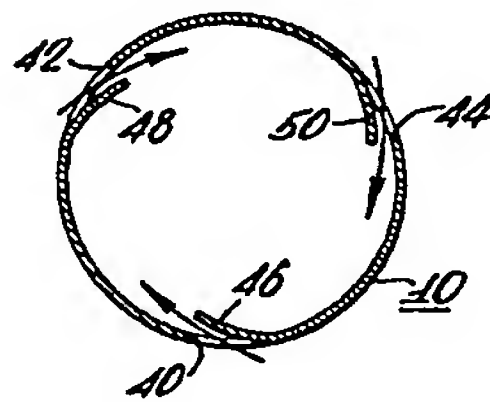


FIG.4.

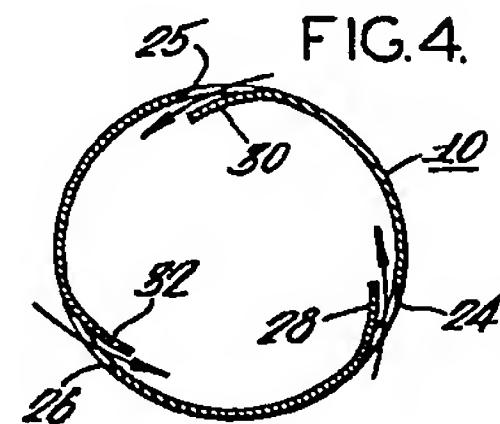


FIG.5.

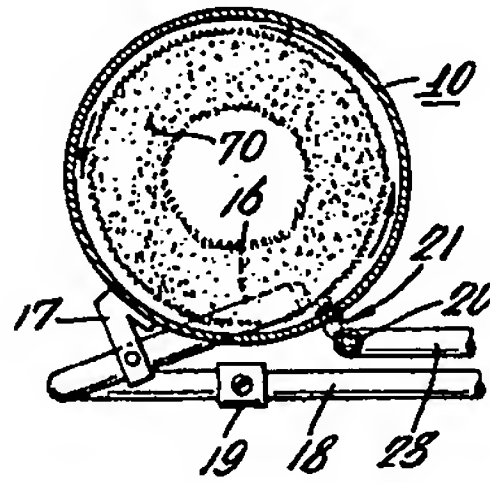


FIG.6.

